1994

Challenging student alternative frameworks of electrical circuits

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CHALLENGING STUDENT ALTERNATIVE FRAMEWORKS OF ELECTRICAL CIRCUITS

By

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A Thesis Submitted in Partial Fulfilment of the Requirements for the Award of Bachelor of Education with Honours at the Faculty of Education, Edith Cowan University

Date of Submission: 2. 8. 94

USE OF THESIS

ABSTRACT

Student alternative frameworks were found by the researcher to be a problem when teaching the topic of electricity to Year 9 science students. It was recognised that the alternative frameworks had to be identified and a constructivist teaching strategy that would facilitate conceptual change within these students needed to be adopted.

A pre-test-post-test, control group-treatment group study was conducted to evaluate the effectiveness of a constructivist approach to instruction. The treatment group in the study received instruction based on the 'four phase model for teaching for conceptual change', a constructivist approach to teaching suggested by Cosgrove and Osborne (1985) as being effective in catering for students with misconceptions of electricity. Whilst the control group received traditional instruction. The period of instruction for both the control and treatment groups was three weeks. Student conceptions were assessed using a pencil and paper test composed of 20 multiple choice questions, in which common student alternative frameworks of electricity were used as distractors, and five short answer questions. The short answer questions required students to provide personal definitions of the key electricity terms current, circuit, resistance, voltage and battery. To provide case study information, interviews were carried out with a sample of three students from each group both prior to and on completion of instruction.

It was found that the teaching program based on a constructivist approach was substantially more effective in bringing about conceptual change than the traditional one. The constructivist approach to teaching, based on Cosgrove and Osborne's (1985) conceptual change model, is recommended for the teaching of the topic electricity. It is also recommended that further research be conducted into the use of this approach for teaching other science topics.

DECLARATION

I certify that this thesis does not incorporate, without acknowledgment, any material previously submitted for a degree or diploma in any institution of higher education and that, to the best of my knowledge and belief, it does not contain any material previously published or written by another person where due reference is made in the text.

Lauril Jones

ACKNOWLEDGMENTS

I acknowledge, with gratitude, the support, advice and encouragement provided by my supervisor, Dr Mark Hackling. His attention to detail and willingness to help were major contributions to this study.

I also acknowledge, with appreciation, the efforts of my husband Lloyd. His technical expertise and assistance has proved invaluable.

Finally I wish to acknowledge the participation of my professional colleagues. Without their cooperation this study could not have been conducted.

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CHAPTER 1: INTRODUCTION

Introduction

Electricity is a topic in the Western Australian high school science curriculum that is usually covered at the Year 9 level. The classroom teacher is faced with a substantial problem when attempting to teach the topic effectively . Upon commencing the topic, the students already possess some type of understanding of the concepts involved. Many of the conceptions are not scientifically acceptable and are known as alternative frameworks. These alternative frameworks are highly resistant to change (Posner, Strike, Hewson & Gertzog, 1982) and must be identified and addressed if the teaching program is to be successful.

The Research Problem

High school students often possess alternative frameworks regarding the nature of electricity (Dupin & Joshua, 1987; Fredette & Lochhead, 1980; Osborne & Freyberg, 1985; Psillos & Koumaras, 1988; Shipstone, 1984; Mestre & Touger, 1989). There is a need when teaching electricity, to identify the nature of these alternative frameworks and to develop a teaching strategy that will facilitate conceptual change within these students.

Rationale and Significance of the Study

In the past, science teachers have failed to adopt teaching strategies that identify and modify alternative frameworks. As a result, although students may have achieved acceptable grades, their alternative frameworks have remained largely uninfluenced by science teaching (Tasker, cited in Osborne & Wittrock, 1983). As such, it is vital that teachers identify students' alternative frameworks and adopt conceptual change strategies that promote the accommodation of students' alternative conceptions towards more scientifically acceptable conceptions.

Purpose and Research Questions

The purpose of this study is to implement and evaluate the effectiveness of a conceptual change strategy (Cosgrove & Osborne, 1985) for accommodating students' alternative frameworks. More specifically the study addresses the following research questions:

1. What alternative frameworks are held by Year 9 students for the concepts of circuit, current, resistance and voltage prior to instruction?
2. To what extent can the frequency of these alternative frameworks be reduced by instruction based on a conceptual change model?

CHAPTER 2: LITERATURE REVIEW

Introduction

The process of learning is a complex matter. A recent theory as to how learning actually occurs has been outlined by Osborne and Wittrock (1983) who suggest that it is a generative process. Novak (1984) proposes that the very nature of this process gives rise to misconceptions .

The alternative frameworks that students possess in relation to the nature of electricity can be grouped into the major areas of current, voltage and resistance. Constructivist learning theory is based on the premise that these alternative frameworks must be addressed if teaching is to be effective. Cosgrove and Osborne (1985) present a four phase model of teaching that is based on constructivist learning theory. By following this model a teacher identifies students' alternative frameworks, links learning to past experience, challenges students' alternative frameworks and enables learning to take place in context.

Learning Theory

Ausubel, Novak and Hanesian (1978) define concepts as "objects, events, situations or properties that possess common criterial attributes and are designated in any culture by some accepted sign or symbol" (p. 89). Osborne and Wittrock (1983) suggest that children have their own theories as to the nature of objects, events and situations prior to instruction. They propose that children develop these alternative frameworks from their contact with the social and physical milieu. Learning then becomes idiosyncratic where individuals construct meaning from their different prior knowledge. Concepts however, are not isolated, they are parts of structures which provide a coherent understanding of the world. Research by Novak (1984) supports this idea. For example he states that "concepts grow in meaning as an individual learns more new propositions in which a given concept is embedded" (p. 607).

The generative learning model (Osborne & Wittrock, 1983) takes into acccunt students' alternative frameworks. It is a model of the teaching-learning process that is based on the theory that learning is an active process which is affected by one's experience. In the generative learning model the brain, "actively constructs it's own interpretations of information and draws inferences from them ... the brain ignores some information and selectively attends to other information" (Osborne & Wittrock, 1983, p. 492). During the process of learning and concept development "people retrieve information from long-term memory and use their information processing strategies to generate meaning from the incoming information, to organise it, to code it, and to store it in long-term memory" (Osborne & Wittrock, 1983, p. 493).

Common Student Misconceptions of Electricity

Recent research (Dupin & Joshua, 1987; Fredette & Lochhead, 1980; Osborne & Freyberg, 1985; Psillos & Koumaras, 1988; Mestre & Touger, 1989; Shipstone, 1984) reveals that many students have misconceptions about the nature of direct current (dc) electrical circuits. These misconceptions may be categorised into the three major areas of current, voltage and resistance.

Students believe that current is consumed by some or all of the components of the circuit (Shipstone, 1984). Some misunderstand the direction of flow and others fail to recognise the passing-through aspect in a circuit. (Fredette & Lochhead, 1980; Gauld, 1988; Osborne & Freyberg 1985; Shipstone, 1984).

Osborne and Freyberg (1985) illustrate three common misconceptions of current flow in a circuit when a globe is connected to a battery in series. Firstly, the wire returning to the battery (connecting the globe to the negative terminal) does not carry current. This misconception demonstrates a student's inability to understand the passing through aspect of current flow. Secondly, current approaches the globe from the battery in the wires from the positive and negative terminals, and the globe glows a direct result of the current clashing inside. Here, students' fail to understand both the passing-through and direction of flow aspects of current in a circuit. Finally, although

current comes from the positive terminal of the battery, passes through the globe making it glow and goes back to the battery, the amount of current returning to the battery is less than the original. This illustrates that students have failed to understand the concept of conservation of current within a circuit.

Dupin and Joshua (1987) and Shipstone (1984) argue that students do not consider the circuit as a system; instead they read a circuit as a sequence in the direction of current flow. Students also tend to confuse the concepts of 'power' and 'current' mixing the terms and using them inappropriately (Shipstone, 1984).

Students also have misconceptions of batteries and the nature of voltage within a circuit. Psillos and Koumaras (1988) and Dupin and Joshua (1987) identified that many students conceive batteries as a constant source of current. That is as a type of 'current reservoir' within a circuit rather than a device that maintains a constant voltage across its terminals. Psillos and Koumaras (1988) also found that the term 'volt' to a significant number of students meant the 'quality' of either current or energy in a circuit rather than the quantity of potential difference.

Research by Shipstone (1984) has revealed two main misconceptions of resistance within an electric circuit. Students are found to maintain that, "the effect of increasing a resistor is not necessarily the inverse of deceasing it" (Shipstone, 1984, p. 189). They also believe that a resistor situated before a lamp will have an effect on the lamp's brightness, but a resistor situated after a lamp will not have any effect on the lamp's brightness.

Causes of Student Misconceptions

Misconceptions arise from either one or a combination of the following factors:

a) the learner not making a conscious effort to "relate knew knowledge to knowledge he or she already has." (Novak, 1984);

b) students' interpretation of personal experiences (Novak, 1984);

c) as a consequence of a teacher ignoring pre-existing alternative frameworks in the teaching-learning process (Nussbaum & Novick cited in Osborne & Freyberg, 1985 p. 103); or

d) a teacher's lack of subject knowledge.

Teachers should therefore familiarise themselves with scientific views, identify student alternative frameworks, and employ a teaching strategy that facilitates conceptual change within all students. A scientifically accurate explanation of electricity concepts can be found in Appendix 1.

Addressing Students' Alternative Frameworks

The four phase model of teaching for conceptual change (Cosgrove & Osborne, 1985) which is based on constructivist learning theory, incorporates all of these essential factors. It can be used effectively to teach the concepts involved in electricity to junior high school students. According to the four phase model of teaching for conceptual change teachers prepare by determining how scientists view direct current electrical circuits and identifying student alternative frameworks. Prior to instruction, teachers also familiarise themselves with the historical and experimental background to the topic of electricity. This initial stage for the four phase model is called the *Preliminary Phase*. It can be achieved by the teacher studying available research data and/or having students complete a pencil and paper test that probes their conceptions of electricity.

During the second stage a *Focus Phase*, context for later work is established and learning becomes linked to familiar experiences which inherently provides motivation. Activities are used to focus student attention on relevant concepts of electricity and on their own meaning for the terminology to be used. These activities serve two functions: student alternative frameworks are made explicit and student motivation is provided.

The *Challenge Phase* enables discussion of student views ensuring all the views are considered. This phase clarifies student views and at the same time

nurtures reconstruction of a concept. Students discuss the views held by others and laboratory tests are conducted to challenge student conceptions while providing evidence for the scientific view of the concept. The final stage of the model is the *Application Phase*. Here, learning is reinforced and provision is made for extension of student learning. This occurs through the application of the new conception to new contexts and problem solving. This enables the students to think reflectively about the phenomenon by viewing it in a new manner.

Many benefits occur when using the four phase model of teaching. The teacher's own views of a concept are clarified prior to teaching (preliminary phase). Students have the opportunity to express their thoughts about a concept (focus phase) and as such the range of student views are explored (focus and challenge phases). Cognitive conflict is created when alternative frameworks are challenged by discrepant data (challenge phase). Students are given the opportunity to consolidate their learning (focus, challenge and application phases) as well as learn in context (application stage).

From a review of the literature, it is possible to see that students' alternative frameworks regarding electricity are many and varied. These alternative frameworks are tenacious in nature, arising from a number of sources. For conceptual change to take place these must be identified and addressed. One suggested method for teaching for conceptual change is by using a four phase model (Osborne & Freyberg, 1985) which is based on a constructivist approach. Before such a method is widely used its success in a variety of classroom situations must be evaluated.

CHAPTER 3: METHODOLOGY

Introduction

This study was conducted using a pre-test-post-test, control group-treatment group design. The control group were taught the topic of electricity in a traditional manner whilst the treatment group were taught using Cosgrove and Osborne's (1985) conceptual change model. The teachers of the control and treatment groups both had prior experience teaching the electricity topic following a traditional program. The teacher of the treatment group in this case was also the researcher. This gives rise to some methodological limitations.

Subjects

The subjects involved in this study were a group of Year 9 students. They had been identified as having well-above average science ability, based on their Year 8 results, and had been streamed as such. The students were a mixture of males and females, between the ages of 13 and 14 who attended a metropolitan Catholic secondary school.

Procedure

The subjects were separated into two groups, both of which completed a pre-test, received instruction and completed two post-tests. Three students who possessed many alternative frameworks were selected from each group for interviewing. The interviews took place both prior to, and upon completion of instruction. The student responses to the interview questions were taped recorded and used to provide information for individual case studies.

After the initial interviews and the pre-testing, one of the groups, the control group, received a traditional method of instruction. This involved the students being: instructed by the teacher in a chalk and talk manner; reading relevant textual information to support what had been taught; and conducting experiments to verify the facts taught.

In parallel with this, the treatment group received instruction based on the conceptual change model (Cosgrove & Osborne, 1985). This involved a program being specifically designed to alter the students' alternative frameworks of electricity that had been identified in their pre-test responses. On completion of instruction, which took place over a three week period, both control and treatment groups were post-tested twice. The tests were administered with a two day interval between one another.

Data Collection and Analysis

Test

The same pencil and paper test instrument, presented in Appendix 2, was used for the pre and post-tests. The instrument consisted of 20 multiple choice questions and five short answer questions. In the multiple choice section of the test each of the key concepts of electricity were tested with common student misconceptions used as distracters. These items enabled the researcher to determine the frequency of misconceptions prior to and following instruction.

The tests were scored out of a possible 25 marks. The multiple choice section being worth 20 marks and the short answer section being worth five marks. In the multiple choice section of the test, each correct answer was given one mark However, where true/false multiple choice questions were concerned, only those answers accompanied by a scientific explanation of the response were deemed correct. In the short answer section of the test each correct answer was also given a single mark. An answer was deemed correct when at least two out of three possible specific criterial attributes were present. MINITAB was then used to calculate the product moment correlation coefficient between the student's test two and test three scores to indicate the level of test-retest reliability.

The data collected from test one and test two were analysed to provide information about each group. A t-test for independent samples indicated that the difference between the two groups' mean scores on the pre-test was approaching

significance. This being the case, equivalent groups of 21 students from each class were selected for study. Members of the groups were selected by matching students in the control group with those in the treatment group with the same test one score. The frequency with which students in these groups selected alternative responses on multiple choice questions in test one was then calculated. This information was compared to the students' test two scores and used to determine the extent of student misconceptions of circuit, current, resistance and voltage prior to and on completion of instruction.

Interviews

In the case of the six interviewees, each was interviewed twice, once before instruction and once again on its conclusion. The interviews were conducted by the researcher using the instrument presented in Appendix 3.

The interview results provided specific information about the nature of individual's conceptions of electricity. The interview situation also provided the students with the opportunity to express any misconceptions which they possessed that were uncommon or even unique. The interview responses in conjunction with the test results provides triangulation of data and as such, convergent validity was achieved. The data analysis then provides information about the nature of alternative frameworks and the extent to which they have been accommodated towards more scientific conceptions of electricity.

Limitations

It must be noted however, that this study has some methodological limitations. The class studied is not representative of the general Year 9 population. The sample is only a small number of students of those in only one particular school. Another factor that should be taken into account when interpreting the results is that students are recognised as being of advanced ability and as such the lower and average ability students are not represented in the sample. Thus, this sample group is not typical of the population, a feature that limits the external validity of the study.

It is also possible that the results are not a true representation of the groups' learning. That is, the results may be influenced by the John Henry effect and/or the Hawthorne effect. The analysis of information gained solely from the interview may in addition be influenced by the halo effect. These factors limit the internal validity of the study.

The concluding interviews also have methodological limitations. The final interviews should have been conducted by someone other that the researcher as she may have become a threat to freedom of expression. That is, instead of a student feeling free to respond in a natural manner he/she may have felt compelled to answer in a way that was expected. However, due to the lack of resources, it was not possible to arrange for an independent interviewer.

CHAPTER 4: RESULTS

Introduction

This chapter presents the treatment and control groups' tests one, two and three results. The students' test two and test three scores are correlated using Pearson *r* to establish the reliability of the test instrument. As the two classes were not equivalent at the test one level, equivalence of control and treatment groups was established by using matched sub-groups within each class. The two groups' responses to test one are then analysed to determine the pre-instruction alternative frameworks the students have in relation to electricity.

Having established the reliability of the instrument, the equivalence of the control and treatment groups and the alternative frameworks of those involved in the research, it is then possible to directly compare the two groups' test scores. The comparison is based on the control and treatment groups' test one and two responses to the 25 items in the test instrument. Interview responses are used to illustrate the differences in students' conceptions before and after instruction. Convergent validity of data is established by comparing the test results and interview data from the six students (three from the control group and three from the treatment group).

Reliability of the Test Instrument

The control and treatment classes' test two and three results were used to calculate the instrument's test - retest reliability. The product moment correlation coefficient between all student's test two and test three scores is 0.82, indicating according to Gay (1992) a good level of reliability. That is, the sources of error in the scores, such as conditions of administration and ambiguous test items, have been minimised to a large extent.

Equivalence of Control and Treatment Classes

The test one (pretest) scores for the intact control and treatment classes were compared to assess the equivalence of the classes. Descriptive statistics presented in Table 1 indicate a higher mean test one score for the treatment class (8.78) than the control class (7.44). A t-test for independent samples indicates that the difference between the classes' means is approaching significance ($t = 1.70$, $p = 0.095$, $df = 57$).

It was therefore decided to select groups from within the two classes on the basis of matched test one scores. These groups are used to evaluate the effectiveness of instruction in changing students' conceptions of electricity.

Table 1: Descriptive Statistics for the Control and Treatment Classes

Class	Number of students	Mean	Standard deviation
Control	32	7.44	2.80
Treatment	27	8.78	3.19

Twenty-one students from each class were selected to form the treatment and control groups. The particular students were chosen on the basis of having a test one score that could be paired directly with a member of the other group (either treatment or control) and having completed at least test one and test two of the possible three tests.

Comparison of the Before and After Instruction Test Scores for the Treatment and Control Groups

Descriptive statistics for test one (before instruction) and test two (after instruction) scores for the matched treatment and control groups are presented in Table 2. In test one, the matched control and treatment groups had identical means (8.19). In test two the treatment group's mean score (17.19) was higher that of the control group (13.24). A two-tailed t-test for independent samples indicates that the difference is significant ($t = 3.73$, $p < 0.01$, $df = 40$). Instruction based on a

conceptual change teaching strategy therefore, produced higher test two scores than traditional instruction.

Table 2: Test One and Test Two Scores for Matched Control and Treatment Groups

		Test one		Test two	
Group	Number of students	Mean	Standard deviation	Mean	Standard deviation
Control	21	8.19	3.19	13.24	3.22
Treatment	21	8.19	3.11	17.19	3.63

Common Student Alternative Frameworks of Electricity Before Instruction

As common student misconceptions of electricity were used as distractors in the multiple choice items of the test instrument, it is possible to identify common alternative frameworks of electricity for the combined control and treatment groups before instruction. This can be done by analysing the frequency of responses to each of the distractors in test one. Table 3 presents the distractors that represent the misconceptions selected by 33% or more of the students in the combined control and treatment groups.

Table 3: Test Item Distractors Representing Misconceptions Selected by more than 33% of Students in the Control and Treatment Groups Before Instruction

Item	Misconception	Frequency %
2B	In a circuit with a globe, the current travels out of the battery from both terminals, clashes in the globe and causes it to glow.	33.3
2C	In a circuit containing a globe, current leaves the positive terminal of the battery and travels to the globe; some current is used by the globe in order to glow; the remaining current returns to the battery's negative terminal.	40.5
4D	Current does not require a complete pathway for it to flow.	38.1
6A	A globe in a circuit uses up some of the current.	61.9
15A	The total voltage drop across a parallel circuit is less than the total voltage drop across a series circuit with the same size battery.	35.7
16A	Two globes of equal resistance in a parallel circuit, shine less brightly that one globe (of the same size) in a series circuit with the same size battery.	59.5
17B	When decreasing the resistance before a globe, in a circuit, the globe shines less brightly.	38.1
18A	When increasing the resistance before a globe, in a circuit, the globe will shine more brightly.	47.6
19A	When increasing the resistance before a globe, in a circuit, the globe shines more brightly.	38.1
20B	When decreasing the resistance after a globe, in a circuit, the globe will shine less brightly.	42.9

Note: The level of 33% or more of students choosing test item distractors was an arbitrarily chosen figure.
Questions 17-20, while refering to current flow in a circuit, are not probing student understanding of electron flow from an area of high potential to an area of low potential (nor conventional flow of positive charge) rather the idea of the circuit as a system.

Control and Treatment Groups' Test Scores for Nine Electricity Concept Areas

The data presented in Table 4 enables a comparison to be made between each groups' initial understanding of nine major electricity concept areas (test one) and the learning outcome after instruction (test two). As such, judgements can be made as to the effectiveness of using a constructivist teaching approach as opposed to a traditional method.

Table 4: Comparison of Control and Treatment Groups' Test Scores Before (Test One) and After (Test Two) Instruction

Concept area	Test item	Control group (n = 21)			Treatment group (n =21)		
		Number of students with correct response		% changing to correct response	Number of students with correct response		% changing to correct response
		Test one	Test two		Test one	Test two	
Components	1	16	19	14.3	10	21	52.4
of a circuit.	3	19	19	0.0	13	19	28.6
	4	12	17	23.8	11	16	23.8
	5	16	13	-14.3	16	17	4.8
	25	9	12	14.3	12	18	28.6
				7.6			**27.6**
Nature of	2	3	9	28.6	5	16	52.4
current flow	7	19	18	-4.8	13	20	33.3
in a circuit.	21	0	13	61.9	7	17	47.6
				28.6			**44.4**
Energy conversion in a globe.	6	6	5	-4.8	9	11	9.5
Interrelationship	8	1	4	14.3	1	10	42.9
of current, voltage	12	3	4	4.8	1	2	4.8
and resistance	13	7	10	14.3	14	16	9.5
in a circuit.				**11.1**			**19.0**
Distribution of	9	4	11	33.3	5	9	19.0
voltage among	10	10	11	4.8	14	14	0.0
components of	11	3	7	19.0	5	12	33.3
a series circuit.				**19.0**			**17.5**
Distribution of	14	6	13	33.3	1	14	61.9
voltage among	15	2	4	9.5	4	11	33.3
components of	16	3	3	0.0	2	2	0.0
a parallel circuit.				**14.3**			**31.7**
Effect of changing	17	4	13	42.9	3	18	71.4
the resistance in	18	4	11	33.3	2	15	61.9
a series circuit.	19	5	13	38.1	2	19	81.0
	20	5	11	28.6	2	16	66.7
	23	1	14	61.9	5	15	47.6
				41.0			**65.7**
Nature of voltage.	22	0	18	85.7	0	15	71.4
Nature of a voltage source.	24	14	13	-4.8	15	17	9.5

Note: Items 1-20 are multiple choice questions, and 21-25 are short answer questions.

Bold figures indicate average percentage change for a given concept area.

Table 4 shows that both groups had achieved a general increase in understanding of electricity after instruction. However, the treatment groups' post-instruction understanding of the concepts was greater than that of the control groups' in seven of the nine concept areas. The exceptions being the distribution of voltage among components of a series circuit, and the nature of voltage.

It should also be noted that the treatment group had an increase in understanding in all concept areas, whereas the control group's understanding actually decreased in regards to the concept of energy conversion in a globe, and the nature of a voltage source. The greatest increase in student understanding, both in the control and the treatment groups, occurred in the concept areas of the nature of voltage, the effect of changing the resistance in a series circuit, and the nature of current flow in a circuit.

Student Responses to Short Answer Test Questions

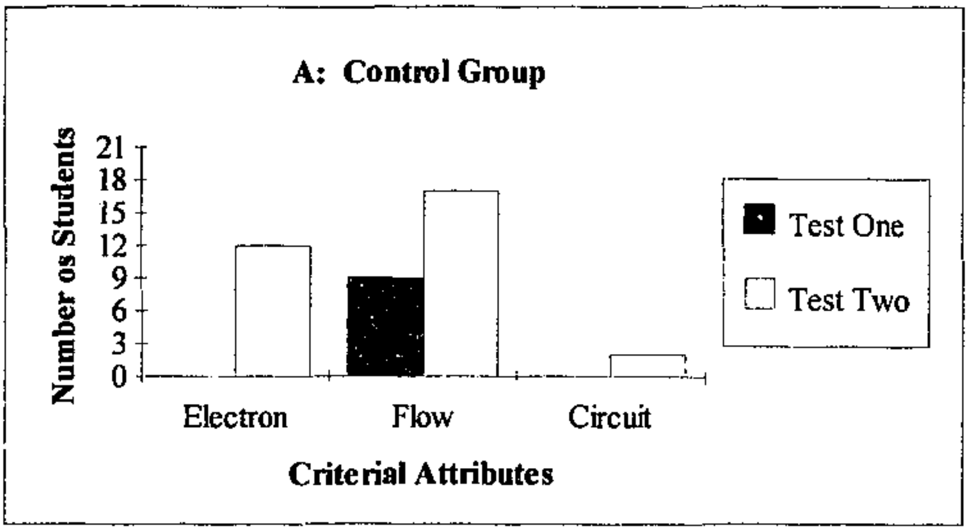
Table 5 presents sample typical responses to the short answer section (questions 21-25) from students in control and the treatment groups before and after instruction.

Table 5: Sample of Student Responses to the Short Answer Questions Before and After Instruction.

	Item		Sample responses	
Concept	number	Group	Test one: Before instruction	Test two: After instruction
Current	21	Control	Is the way in which energy enters the object.	A flow of electrons.
		Treatment	The flow of electricity.	The flow of electrons in a circuit.
Voltage	22	Control	The amount of power in it.	The force that moves electrons.
		Treatment	The amount of power the battery uses.	The force of which electron are pushed through a circuit.
Resistance	23	Control	I don't know.	The force stopping the electrons through.
		Treatment	A thing that resists power going through it.	To stop or lesson the force of electrons in the circuit.
Battery	24	Control	An object, which gives power for an object to work.	Is stored chemical energy, electricity produced by chemical reaction.
		Treatment	Energy storer.	The source of electrons.
Circuit	25	Control	When wires and batteries are connected and make electricity.	Something that has a globe, wires and a power source.
		Treatment	Is the wiring of the object voltage goes through.	A pathway where electrons can flow.

Student Explanations of the Term Current

Student explanations of the concept current (see Figure 1) were analysed in terms of the criterial attributes of electrons, flow and circuit. Current being scientifically defined as the **flow** of **electrons** within a **circuit.** After instruction both groups showed a large increase in use of the term electron. Only one student in the two groups used the term electron prior to instruction, whereas a total of 39 students included it in their response following instruction. This further illustrates that learning occurred in both the control and the treatment groups.



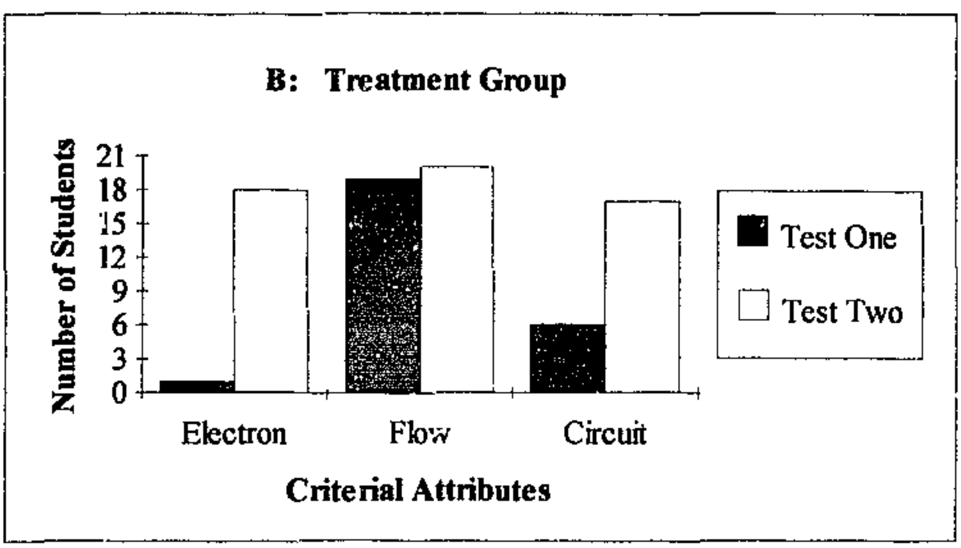


Figure 1. Number of Students Using Various Attributes to Define the Term Current.

Student Explanations of the Term Voltage

Student explanations of the term voltage were analysed in terms of the criterial attributes force, push and electrons (see Figure 2). Voltage being defined for our purposes as the **force** which **pushes electrons**. The test one results indicate a very poor understanding of voltage in both groups prior to instruction with only one student identifying one criterial attribute for the concept. However, the test two responses illustrate a marked improvement in students' conceptions following instruction.

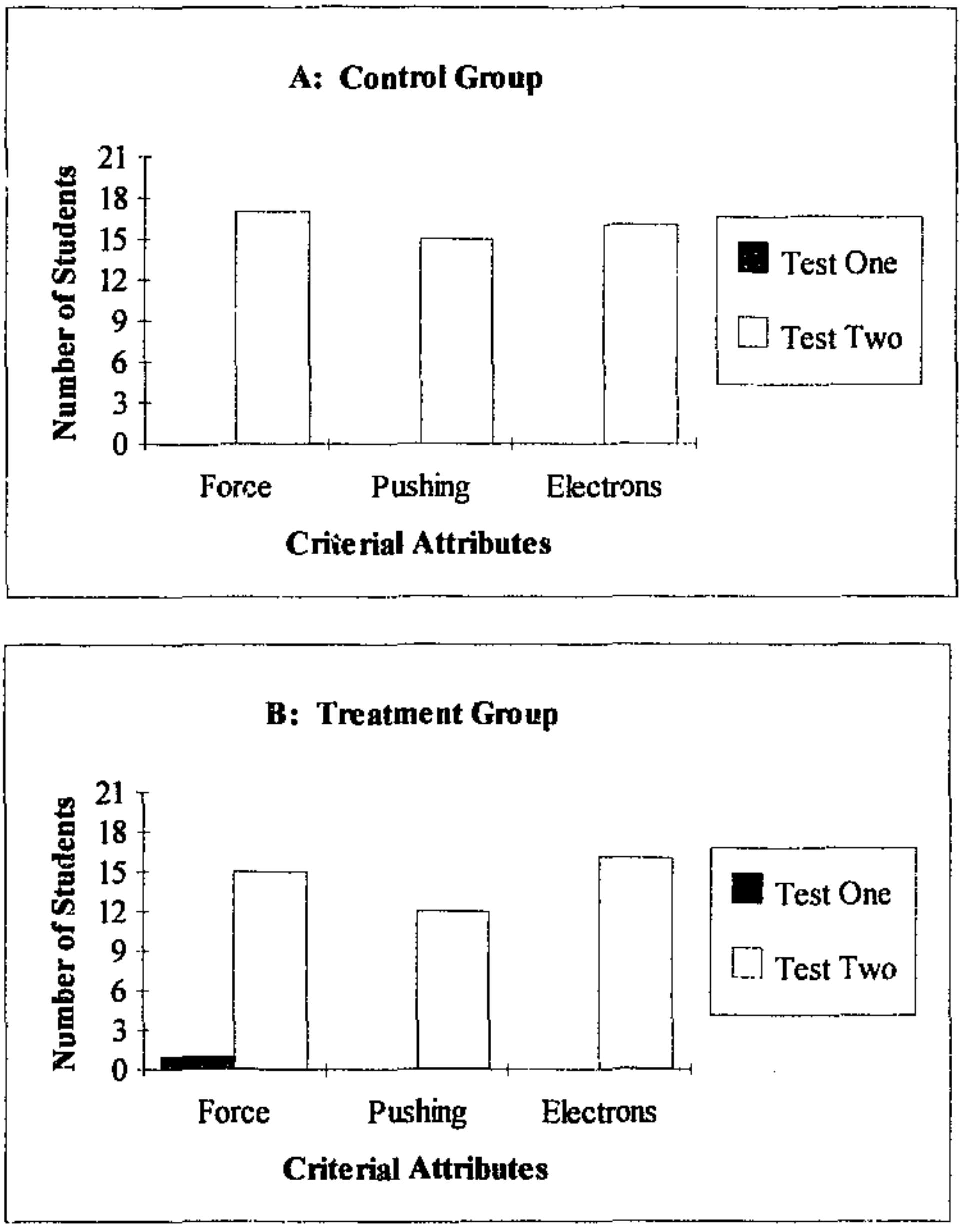


Figure 2. Number of Students Using Various Attributes to Define the Term Voltage.

Although not shown in the graph, it should also be noted that 12 students (A02, A03, A10, A20, A23, A26, B04, B05, B19, B24, B29 and B30) used the global term electricity in their initial definition of voltage, whereas only student B23 used this term following instruction. Many students changed to the more scientific terminology in test two.

Student Explanations of the Term Resistance

Student explanations of the concept resistance were analysed in terms of the criterial attributes of opposition, flow and electron (see Figure 3). Resistance being defined as **opposition** to the **flow** of **electrons** within an electric circuit.

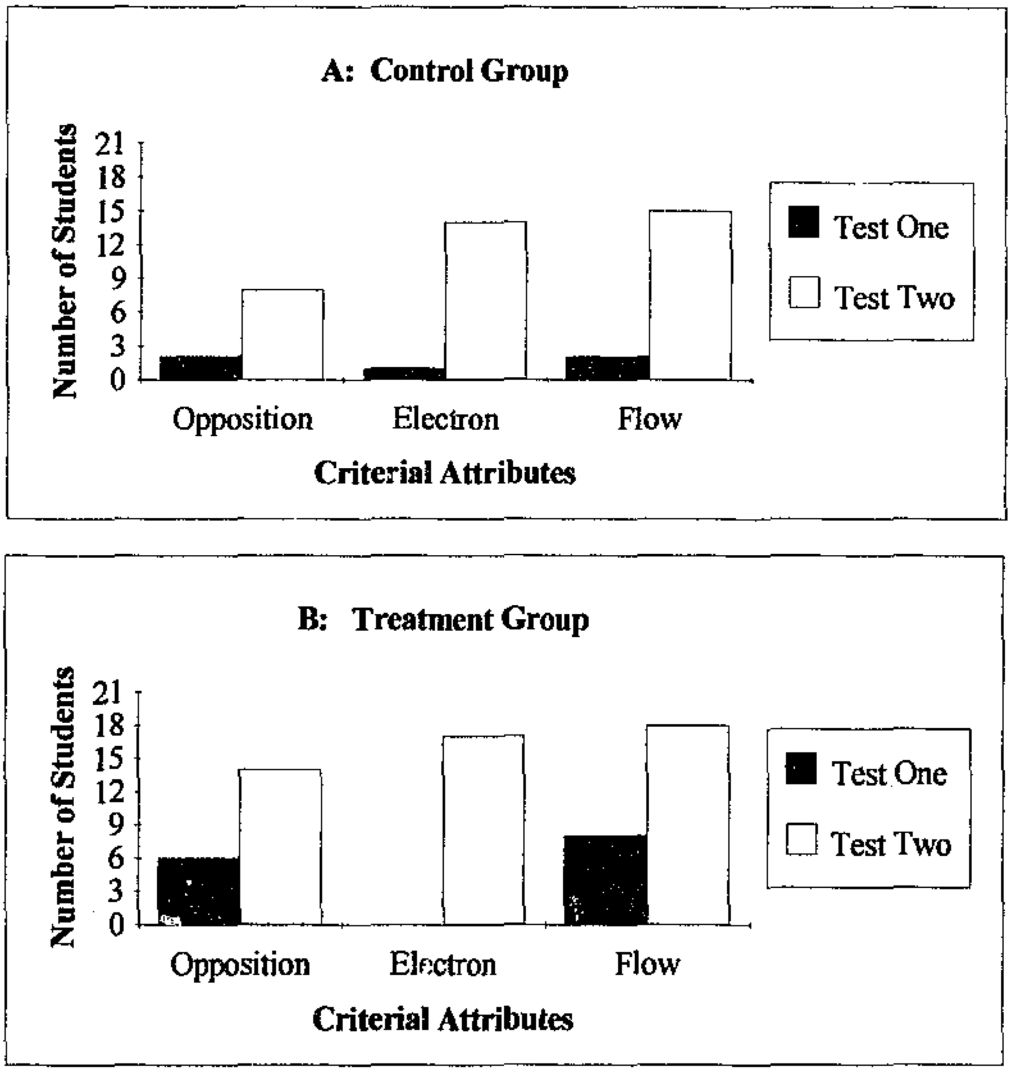


Figure 3. Number of Students Using Various Attributes to Define the Term Resistance.

It is important to note that in the test two responses, a significant number of students used the term electricity interchangeably with the term electron. Not shown in Figure 3, as an initial response to test one, three students (B16, A25, A27,) defined the term resistance as used in common English. Whereas, no students did this in test two. In test one, the term Ohm was not used in relation to the definition of the term resistance, however, following instruction two students (A07 and B29) used the term Ohm.

Student Explanations of the Term Battery

Student explanations of the term battery were analysed in terms of the criterial attributes source, electrical and energy (see Figure 4). Battery, for our purposes, being defined as a **source** of **electrical energy**. The treatment group students in their final explanation of the term battery shifted away from the use of the term energy, using 'electron flow' in its place, whereas the control group students in their test two responses avoided any reference to electricity or current.

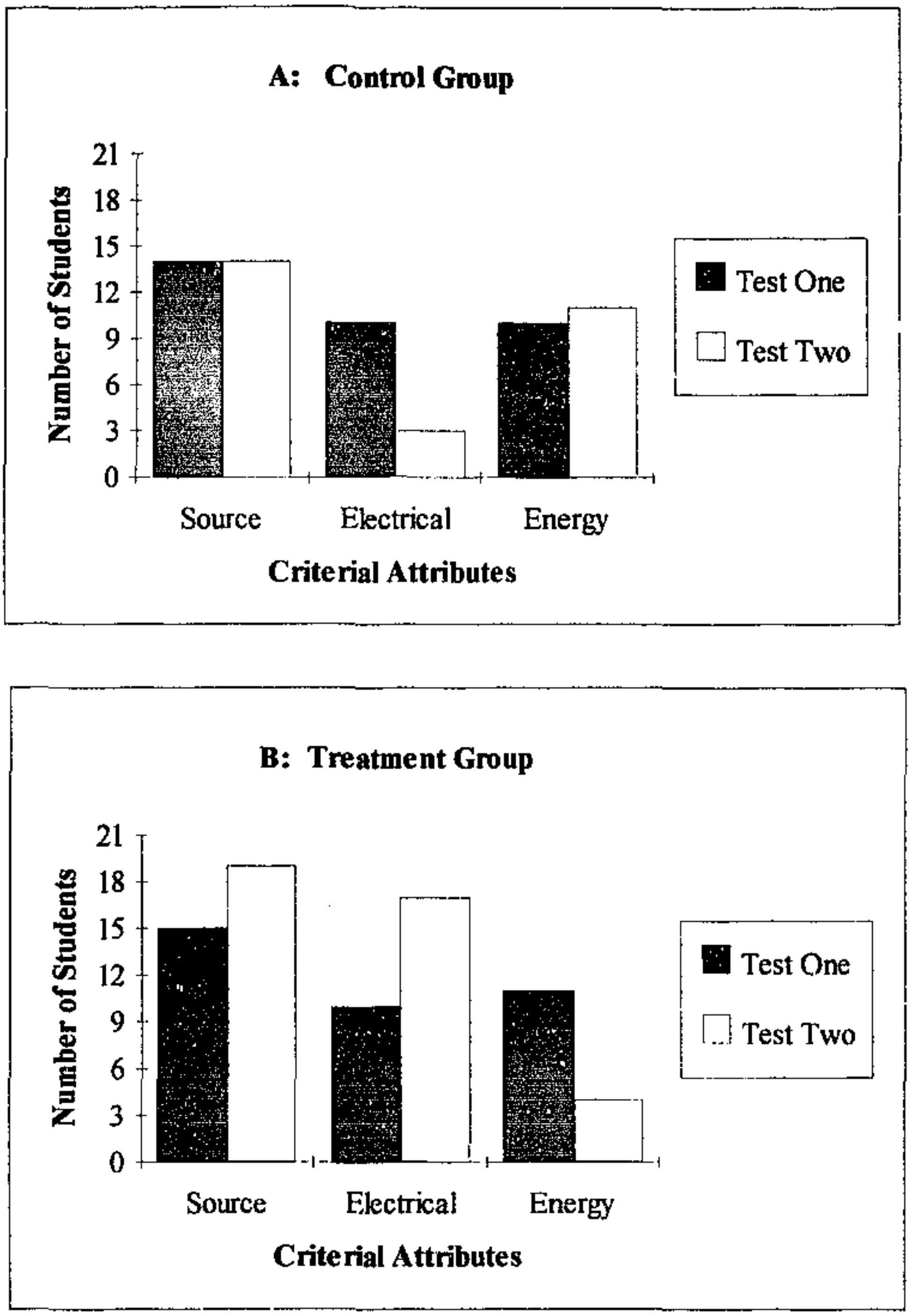


Figure 4. Number of Students Using Various Attributes to Define the Term Battery.

Student Explanations of the Term Circuit

Student explanations of the term circuit were analysed in terms of the criterial attributes pathway, electron and flow (see Figure 5). Circuits being scientifically defined as a **pathway** for **electron flow**.

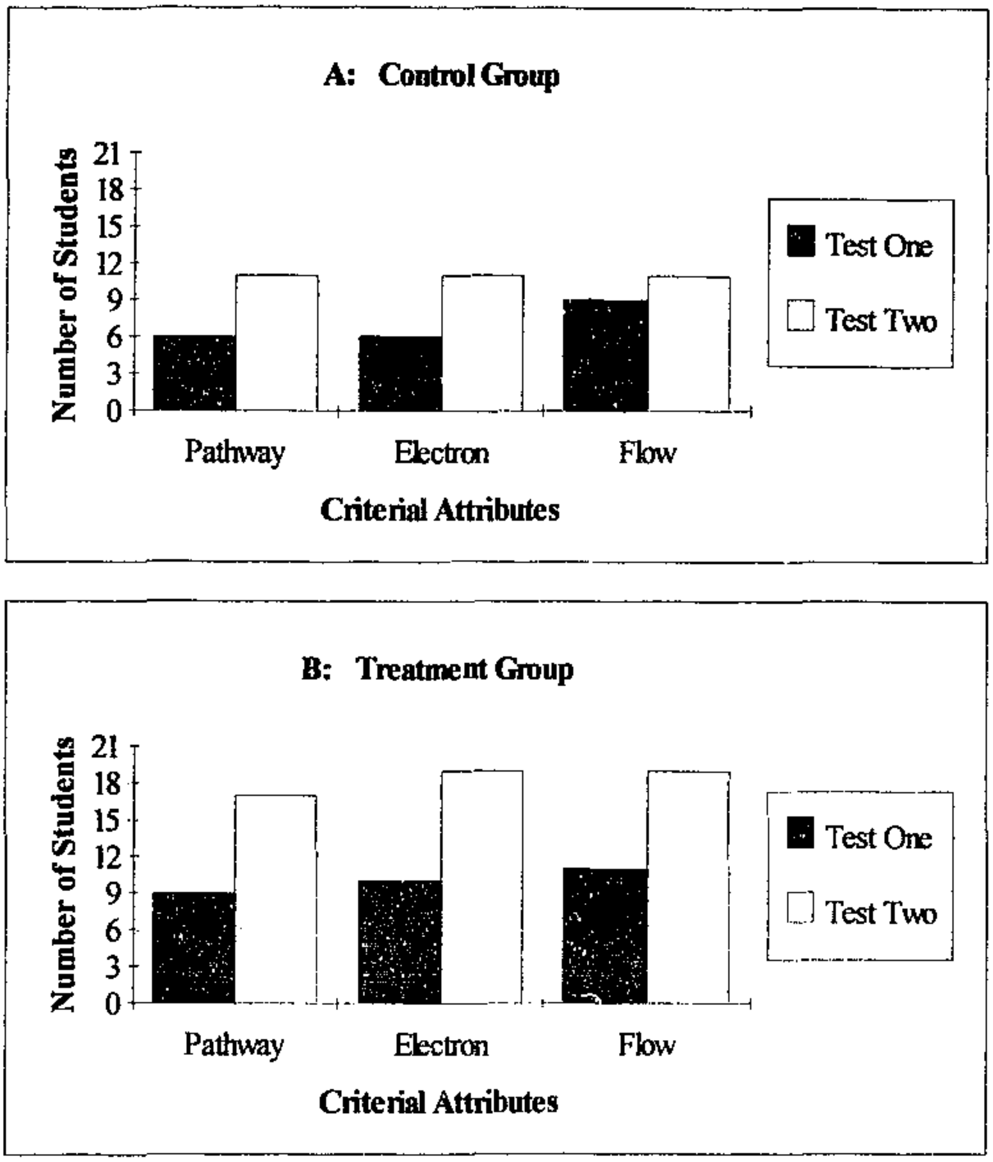


Figure 5. Number of Students Using Various Attributes to Define the Term Circuit.

The responses of several students in the control group (numbers B01, B14, B16, B19, B29 and B30) remained unchanged after instruction. However, this only occurred in one instance (A22) in the treatment group. A significant number of students used the term electricity interchangeably with the term electron following instruction.

Student Responses to Interview Questions

Table 6 presents examples of interview responses to illustrate student conceptions before and after instruction. See Appendix 4 for a transcript of the post instruction interview with student number B27.

Table 6: Sample Student Interview Responses

Concept probed	Student	Interview question	Interview one (Pre-instruction) misconceptions	Interview two (Post-instruction) correct conceptions
Components of a circuit.	A03	Given a globe 3 wires and a battery draw a circuit through which electricity can flow to light up the globe. Does it matter how you've got them arranged?	One wire touching the base of the battery and the top of the battery with the globe.	On the battery, you have one wire coming from the positive and one wire coming from the negative up to the globe. One has to go at the side and one at the bottom so that it can go around.
Nature of current flow in a circuit.	B21	Do any of these diagrams describe the way you think current flows to make the globe glow? In 'A' there is no electric current in the wire attached to the base of the battery. In 'B' the current will be in a direction towards the bulb in both wires. In 'C the direction of the current will be as shown but it will be less in the return wire and in 'D' the direction and the amount of the current will be the same in both the wires.	* **B.** I don't know how a positive charge can go back into a battery as a negative charge.	* **C.** Because the globe has to use the energy to make it glow.
Interrelationship of current, voltage and resistance in a circuit.	B27	Does the globe consume any of the electric current?	Well, I guess so.	*Yes ... the energy.
Distribution of voltage among components of a series circuit.	B27	Does the battery deliver the same voltage whatever circuit that it's in?	Yes at the start but it probably gets used up.	Yes ... because the battery has the same voltage in each case.
Effect of changing the resistance in a series circuit.	A19	If R1 is increased what will happen to the brightness of the globe?	It will go brighter ... because there is no energy going back to the negative.	*It will go dimmer ... because it is stopping the current going to the globe.
Nature of voltage.	A26	What does the term voltage mean?	It's the ... I'm not sure.	The force at which the electrons go through a circuit.

Note: * Indicates a misconception but a distinct improvement on the level of understanding.
Student numbers commencing with 'A' are from the treatment group and those with a 'B' are from the control group.
Bold text indicates the answer selected by the student.

Convergent Validity of Data

Table 7 shows the agreement between certain test items and the responses made to similar questions given by students in an interview situation.

Table 7: Agreement Between Student Responses on Test Two and Interview Two

Item number	B16	B21	B27	A03	A19	A26	Number in agreement	Proportion agreement
	Student							
1	a	a	d	a	a	d	4	0.67
2	a	a	d	a	d	d	3	0.50
3	a	a	a	a	a	d	5	0.83
4	a	d	a	d	a	a	4	0.67
5	d	a	a	a	a	a	5	0.83
6	a	a	a	d	a	a	5	0.83
7	a	a	a	a	a	a	6	1.00
8	d	a	d	d	a	a	3	0.50
11	d	d	d	a	d	a	2	0.33
17	a	d	a	a	a	d	4	0.67
18	a	a	a	a	a	a	6	1.00
19	a	d	d	a	a	a	4	0.67
20	a	a	a	a	a	d	5	0.83
22	a	a	a	a	a	a	6	1.00
Number in agreement	11	10	9	11	12	9		
Proportion agreement	0.79	0.71	0.64	0.79	0.86	0.64		0.74

Note: "a" indicates agreement between the subjects' responses on the two instruments.
"d" indicates disagreement between the subjects' responses on the two instruments.
Student numbers commencing with the letter 'A' are from the treatment group and those commencing with 'B' are from the control group.

The average proportion of agreement between the students' responses on test items and interview answers is 0.74 which indicates a satisfactory level of convergent validity.

Main Findings

Prior to instruction the Year 9 students possessed many and varied alternative frameworks as to the nature of electricity. The most common alternative frameworks prior to instruction were:

- the total voltage drop across a parallel circuit is less than the total voltage drop across a series circuit when the same size battery is used in each case.
- two globes of equal resistance in a parallel circuit shine less brightly than one globe (of the same size) in a series circuit (when the same size battery is used).
- in a series circuit containing a globe, current travels out of battery from either terminal clashing in the globe to make it glow.
- current travels in one direction around a circuit, a part being consumed by the globe making it glow.
- in a series circuit, when decreasing the resistance before a globe, the globe will shine less brightly.
- in a series circuit, when increasing the resistance after a globe, the globe will shine more brightly.
- when increasing the resistance before a globe in a series circuit, the globe will shine more brightly; and when decreasing the resistance after a globe in a series circuit, the globe in the circuit will shine less brightly.

Comparison of the pre-instruction and post-instruction test results for the matched treatment and control groups show that learning occurred in both groups, however, more learning occurred in the treatment than in the control group. That is, the treatment group's test two results were higher than the control group's in seven of the nine concept areas examined and the treatment group showed an increase in understanding in all the concept areas studied, whereas the control group did not.

CHAPTER 5: DISCUSSION

Introduction

In this chapter the results of the research are interpreted and discussed in detail. The misconceptions possessed by the high ability Year 9 students prior to instruction are identified and a comparison is made between test one and two scores for the control and treatment groups in nine conceptual areas of electricity. The comparison indicates that learning occurred in both groups and the treatment group underwent a greater amount of conceptual change than the control group (See Table 2). The control group received traditional teaching which did not take into account the students' prior conceptions, while the treatment group received teaching based on a conceptual change model which was designed to challenge and accommodate students' alternative frameworks. The significant difference between the groups' test two mean scores suggests that instruction based on Cosgrove and Osborne's (1985) conceptual change model was more effective than the traditional instruction received by the control group.

The test comprised 25 items of which the first 20 were multiple choice questions, whereas items 21 to 25 required short answer responses. In the multiple choice section of the test students were asked to distinguish between common misconceptions which were used as distractors and scientifically correct conceptions of electricity. In the short answer section of the test students were asked to define the terms current, voltage, resistance, battery and circuit. Analysis of the test results enables judgements to be made as to the alternative frameworks present before instruction and the amount and nature of conceptual change that occurred within the groups due to the implementation of a traditional teaching program as opposed to one based on constructivist pedagogy.

The Nature of Student Alternative Frameworks Before Instruction

Prior to instruction the Year 9 students displayed alternative frameworks relating to voltage, current, circuit and resistance (see table 3). Although many students had no particular understanding of voltage prior to instruction, which was indicated by the selection of the 'I don't know' response (distractor C) by a large number of students for items eight through to 15, others had identifiable alternative frameworks. Some students considered that the voltage drop across two globes in parallel is less than the voltage drop across one globe in a series circuit with similar components (item 15 distractor A) and/or that two globes in parallel shine less brightly than a single globe in series circuit with similar components (item 16 distractor A).

Many types of alternative frameworks also existed regarding current and circuit. Evidence of this can be seen in the responses to items two, four and six. In response to item 2, current was considered to flow in two directions out of a battery and meet, clashing in the globe, to make it glow (distractor B) or flow in one direction through a circuit with some of it being used up when lighting a globe (distractor C). Some students thought that current does not require a complete pathway to flow (item 4 distractor D) and/or that a globe uses up some of the current to make it glow. These alternative frameworks are consistent with the findings of Fredette and Lochhead (1980), Gauld (1988), Osborne and Freyberg (1985) and Shipstone (1984).

There were also many alternative frameworks regarding resistance in a circuit. Students thought that: decreasing a resistance placed after the globe caused the brightness of the globe to decrease (item 17 distractor B); increasing a resistance placed before the globe causes the brightness of the globe to increase (item 18 distractor A); increasing a resistance placed after the globe causes the brightness to increase (item 19 distractor A); and a resistance before the globe causes the brightness to increase (item 20 distractor B).

Amount of Conceptual Change in the Nine Concept Areas

The test items can be grouped into nine concept areas (refer to Table 4). When comparing the percentage of students changing from an alternative framework to the correct response, students in the treatment group showed a higher level of conceptual change in seven of the nine concept areas. These categories include: the components of a circuit; the nature of current flow in a circuit; the distribution of voltage among components of a parallel circuit; the nature of a voltage source; energy conversion in a globe; the effect of changing the resistance in a series circuit; and the interrelationship of current, voltage and resistance in a circuit. The control group actually exhibited a movement away from the correct response in the categories of energy conversion in a globe, and the nature of a voltage source. The treatment group showed a smaller conceptual change than the control group in only two concept areas; the nature of voltage, and the distribution of voltage among components of a series circuit.

Areas of Greater Conceptual Change for the Treatment Group

Components of a Circuit

In relation to the concept area of components of a circuit, the treatment group had an increase in the number of students changing to the correct response on the completion of instruction compared to the control group. That is, the percentage of students changing to the correct response in the treatment group (27.6) was greater than in the control group (7.6). This conceptual change is illustrated by the following extract from the interviews. Before instruction, treatment group student A03's description of a circuit was, "One wire touching the base of the battery and the top of the battery with the globe." However, after instruction the response had change to, "On the battery, you have one wire coming from the positive and one wire coming from the negative, up to the globe. One has to go at the side and one at the bottom so that it can go around." That is, student A03 had moved from thinking that a globe, connected to the positive and negative ends of a battery with a globe pressed on the

wire attached to the positive end would light a globe, to understanding the correct form of a circuit.

The two groups' use of the criterial attributes pathway, electron and flow (Figure 5) in the definition of circuit (item 25) before and after instruction also help to illustrate this difference. For these criterial attributes, the number of students changing to the correct response after instruction was approximately twice as great in the treatment group than those in the control group. Student responses to this item also show that six of the 21 students' definitions in the control group remained unchanged by instruction, whilst this was the case with only one student in the treatment group. An example which compares the two groups' definitions to the term circuit is given below. Before instruction a member of the control group gave the definition of a circuit as, "When wires and batteries are connected and make electricity." and after instruction as, "Something that has a globe, wires and a power source." In comparison to this, before instruction a member of the treatment group gave the definition of circuit as, "The wiring of the object voltage goes through." and after instruction as, "A pathway where electrons can flow." Examples of activities used to teach the components of a circuit in the successful teaching program based on a conceptual change model are outlined below.

Activity 1. Focus Phase

Class discussion to determine different student opinions on the path current flows in a circuit. If no one suggests the scientific model it should be suggested as an alternative from another viewpoint.

Activity 2. Challenge Phase

Given two wires, a battery and a bulb students practise making the bulbs glow and test each of the circuits proposed in the focus phase.

Activity 3. Challenge Phase

Students are asked to keep accurate drawings of the circuits that they create. They may use words or a constructor's code. This leads to a discussion of conventional symbols and circuit diagrams.

Activity 4. Challenge Phase.

Using a socket, a bulb, two insulated wires and a 1.5V cell, students suggest and learn ways of testing whether or not the lamp is defective or whether the cell is flat.

Activity 5. Application Phase

Problem A: Solving the Christmas tree light problem. If one bulb is in a line of three bulbs (in series) is defective, none of the bulbs will glow. The pupils are asked to experiment to find other ways of arranging the bulbs, so that if any one of them fails the other bulbs will still glow. This should lead to teacher input as to the difference between current flow in a parallel and series circuit.

Problem B: Lighting a tunnel. The bulbs and switches must be arranged so that a person walking through a tunnel can turn on a light for the region of the tunnel where he or she is, then, proceeding further a second light is turned on, and the first light is turned off. The students are required to experiment and present a circuit diagram using conventional symbols to display their answer.

Problem C: Caller indicator for the deaf. The deaf person should be able to see, by looking at one, or two, bulbs whether a visitor is at the front or the backdoor of the house. The students are asked to experiment and present a circuit diagram using conventional symbols to display their answers.

It can be seen from these activities and as suggested by constructivist learning theory that: the teacher is privy to student alternative frameworks at the outset of learning (activity 1); context for later work is established and learning is linked to familiar experiences (activity 3); provision is made for students to discuss their view points and thus clarify their thoughts(activity 2); laboratory tests are conducted to challenge student conceptions (activities 2,3 and 4); and opportunity is provided for students to apply their learning in a new context (activity 5).

Nature of a Voltage Source

There was also a substantial difference in the level of conceptual change between the treatment and control groups in the concept area of the nature of a voltage source. In the treatment group 9.5 % of the students changed towards the correct response after instruction, whereas in the control group 4.8 % of the students changed away from the correct conception. At this Year 9 level the concept battery was described as a source of electrical energy.

Although the treatment group showed an overall improvement in the use of criterial attributes for the concept of battery, there was a decrease in the number of students (11 to four) using the attribute energy. The students described a battery as a source of electrical current rather than a source of electrical energy. This misconception coincides with the finding of Psillos and Koumaras (1988) and Dupin and Joshua (1987) who determined that may students conceive a battery as a current reservoir rather than a device that maintains a constant voltage across its terminals. Although instruction based on a conceptual change model was more effective than traditional instruction, there appears to be a need to improve the approach taken here for teaching about voltage sources.

Energy Conversion in a Globe

For the concept area of energy conversion in a globe 9.5% of the treatment group changed to the correct response while the control group displayed a 4.8 % decrease in correct response. Although the treatment group showed an improvement in this concept area, the extent of the conceptual change is not highly satisfactory. It would seem that in order for an acceptable level of conceptual change to occur, in relation to the concept of energy conversion in a globe, the teaching program based on a conceptual change model needs to be improved by including extra activities in the focus and challenge phases of learning. That is, the program changed to provide students with more opportunity to experience and familiarise themselves with the effect of a globe in a circuit. It must be acknowledged that only one true/false item

was used to assess students' understanding of this concept and therefore the data is likely to be subject to measurement error.

Distribution of Voltage Among Components of a Parallel Circuit

In regards to the concept area of distribution of voltage among components of a parallel circuit, the treatment groups' level of improvement was twice that of the control group. When learning about voltage in parallel circuits, students in the control group; were instructed as to how voltage is distributed, conducted a set experiment to verify theory and completed calculations regarding voltage drops in parallel circuits. The students in the treatment group in contrast, were given the opportunity to explore parallel circuits. This was achieved through group construction of a variety of parallel circuits and the testing of voltage drops with voltmeters in the circuits created (focus phase). On the basis of their experiments, the student groups then created and tested their own theories as to the relationship between parallel circuits and voltage (challenge phase). After class discussion as to the relationship between voltage drops and parallel circuits, individuals were asked to determine voltage drops in parallel circuits on the basis of their understanding (application phase). The constructivist approach was more successful than the traditional approach as it addressed the students pre-existing understandings, gave the opportunity to explore all possible alternatives and provided students with the opportunity to apply their learning.

Current Flow in a Circuit

There was a greater level of conceptual change in the treatment group (44%) than in the control group (29%) for current flow in a circuit. Student B21 illustrates the nature of conceptual change that occurred. This student had a scientifically unacceptable understanding of the concept of current flow in a circuit prior to instruction: "the way in which energy enters to object". The student's pre-instruction response reflected the common misconception of failing to recognise the "passing through" aspect of current in a circuit (Fredette & Lochhead, 1980; Gauld, 1988; Osbourne & Freyberg, 1985; Shipstone, 1984). After instruction, however, the nature

of the conception had substantially improved, and come closer to a scientifically acceptable one: " a flow of electrons".

The large difference in the level of conceptual change is also illustrated in Figure 1. It shows the number of students using the criterial attributes electron, flow and circuit to define the term current. Although learning occurred in both groups, the number of students in the control group that used all the criterial attributes of current after instruction was only one compared to 16 in the treatment group. The constructivist approach was more effective for teaching the concept of current flow than traditional instruction.

Effect of Changing the Resistance in a Series Circuit

The percentage of students undergoing conceptual change regarding the effect of changing the resistance in a series circuit, was greater in the treatment group (66%) than in the control group (41%). Figure 3 indicates that after instruction, eight of the 21 control group students used the criterial attributes of the term resistance (electron, flow and circuit) compared to 11 of the 21 students in the treatment group. Student A19's interview responses illustrate the type of conceptual change that occurred. Before instruction A19 stated that if a resistance is increased the bulb, "Will go brighter ... because there is no energy going back to the negative." That is, prior to instruction a student in the treatment group thought that if a resistance was increased a globe would glow brighter. After instruction A19's response was, "It will go dimmer because it is stopping the current going to the globe". Although this response indicates a misconception an improvement in student level of understanding is evident.

An example of a control group student's post instruction conception of the effect of changing the resistance in a series circuit can be seen in student B27's interview response. Student B27 replied, "It will stay the same ... because that will not effect the current flow going from the negative to the globe." This is consistent with the findings of Shipstone (1984) who noted the common student misconception that a

resistor situated before a globe will have an effect on the globe's brightness, but a resistor situated after a globe will not have any effect on the globe's brightness.

Interrelationship of Current, Voltage and Resistance in a Circuit

The interrelationship of current, voltage and resistance in a circuit is the final concept area tested that depicts a greater level of conceptual change for the treatment group (19%) than the control group (11%). An example of the type of conceptual change that occurred can be found in the sample interview responses. It shows student B27, prior to instruction, responding to the question, "Does the globe consume any of the electric current?" by saying, "Well, I guess so." Yet after instruction the response given is, "Yes ... the energy". Thus exhibiting a change from an uncertain conception before instruction to a more acceptable conception after instruction. The initial response given reflects the common misconception outlined by Shipstone (1984) that some of the current is consumed by a component of the circuit.

Areas of Greater Conceptual Change for the Control Group

The Nature of Voltage

The two areas in which the control group achieved greater conceptual change than the treatment group both involved the concept voltage. In the concept area the nature of voltage, 85.7 % of students in the control group changed to the correct response after instruction, compared to 71.4% in the treatment group. That is, both groups demonstrated considerable conceptual change however, the treatment group's change was less than the change that occurred in the control group.

Figure 2 shows that both groups initially had a very poor understanding of the concept of voltage, yet after instruction the number of students using the criterial attributes of force, pushing and electrons was much larger. Initially only one student out of the 42 identified force as a specific criterial attribute of voltage. After instruction 30 students used this attribute. A specific example of the control group's definition of the term voltage before instruction can be found in Table 6. It illustrates the common misconception that the term voltage, to a significant number of students,

means the quality of either the current or the energy, rather than the quantity of the potential difference as identified by Psillos and Kourmaras (1988) The results in Table 4 and Figure 2 reveal that both teaching programs changed student conceptions of voltage markedly, but the traditional method had a greater effect than the program based on a conceptual change model.

Distribution of Voltage Among Components of a Series Circuit

Both groups demonstrated conceptual change regarding the distribution of voltage among components of a series circuit. However, the percentage of students changing to the correct response in the control group (19%) was slightly higher than the percentage of student changing to the correct response in the treatment group (17.5%).

Main Findings

Students in a high ability Year 9 class possessed a range of alternative frameworks relating to voltage, current, circuit and resistance prior to instruction. By evaluating the students' test results after instruction, it would seem that in this study, the teaching program based on Osborne and Cosgrove's (1985) conceptual change model, was more effective at achieving conceptual change in most aspects of elementary electricity than the traditional teaching program. Evidence of this can be found when analysing student responses to test items that are grouped according to concept areas. It must be noted, however, that although the treatment group achieved greater conceptual change than the control group in seven of the nine concept areas, the control group performed better than the treatment group on the concepts of the nature of voltage, and distribution of voltage among components of a series circuit. Perhaps the very abstract nature of voltage suggests that students are not ready for an understanding of the concepts. The traditional approach with its emphasis on rote learning shows improvement though.

CHAPTER 6: CONCLUSIONS AND IMPLICATIONS

Introduction

This chapter describes the outcomes of the study in terms of the research questions, the implications for teaching and further research. The methodological limitations of the study are also described.

Conclusions of the Study

The study addressed two specific questions. The first of which was; what alternative frameworks are held by Year 9 students for the concepts of circuit, current, resistance and voltage prior to instruction? This group of Year 9 students possessed many and varied alternative frameworks as to the nature of electricity. Common alternative frameworks in relation to current and circuit included: in a circuit containing a globe, current travels out of battery from either terminal clashing in the globe to make it glow; and current travels in one direction around the circuit but part of it is consumed by the globe to make it glow. Common alternative frameworks in relation to voltage included: the total voltage drop across a parallel circuit is less than the total voltage drop across a series circuit, when the same size battery is used in each case; and that two globes of equal resistance in a parallel circuit shine less brightly that one globe (of the same size) in a series circuit, when the same size battery is used.

The common alternative frameworks relating to the concept of resistance before instruction were more extensive. Students thought that: when decreasing the resistance before a globe, the globe will shine less brightly; when increasing the resistance before a globe, the globe will shine more brightly; when increasing the resistance after a globe, the globe will shine more brightly; and when decreasing the resistance after a globe, the globe will shine less brightly.

The second research question was; to what extent can the frequency of these alternative frameworks be reduced by instruction based on a conceptual change

model? This study showed that when comparing the amount of conceptual change that occurred between two equivalent groups, one that received traditional instruction and the other instruction based on Cosgrove and Osborne's (1985) conceptual change model, a teaching program based on constructivist theory was substantially better for achieving conceptual change in students than a traditional program.

Implications for Teaching

The data from this study suggest that an approach based on constructivist learning theory is more effective when teaching Year 9 students the topic of electricity, as it enables conceptual change to take place at a higher level than traditional instruction. It must be noted however, that the particular teaching program used must be modified in order that an acceptable level of conceptual change occurs in all of the conceptual areas probed.

Implications for Further Research

The success of this teaching program, based on Cosgrove & Osborne's (1985) conceptual change strategy, also indicates that teaching programs for other science topics may be more effective if based on constructivist theory. This then could become the basis of further research, however, the limitations of the results obtained must be considered.

The limitations in this study were mainly methodological ones. Firstly, classes studied were not representative of the general Year 9 population, as they are a small number of advanced ability students from only one school. It is also possible that the results are not a true representation of the groups' learning as the results may be have been influenced by the halo effect as the researcher was also the treatment group's teacher, the John Henry effect and/or the Hawthorne which limits the study's internal validity. In terms of the interviews the concluding interviews also have methodological limitations. Ideally they should have been conducted by a person

other that the researcher, as this may have threatened the interviewees freedom of expression. This was not possible, however, due to the lack of available resources.

The above limitations, although seemingly numerous, are minor and do not negate the valuable information for teachers that has been obtained through this study. The significant positive outcome of this study indicates that if science teachers wish to reduce students' misconceptions in the topic of electricity then they should explore the constructivist approach further.

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APPENDIX 1

EXPLANATIONS OF ELECTRICITY CONCEPTS

Students are required to be familiar with the following concepts in order to understand the workings of the electric circuits in the interview questions.

Circuit: a pathway through which electrons can flow.

Voltage: the electrical force that pushes electrons through a circuit. Another name for voltage is potential difference. The unit of measurement of voltage is the Volt.

Current: the flow of electrons within a circuit. The direction of current flow is always from a higher voltage level to a lower voltage level. The unit of measurement of current is the Ampere.

Resistance: opposes the flow of current within an electrical circuit. The unit of measurement of resistance is the Ohm.

Ohm's Law: defines the relationship between voltage, current and resistance in an electrical circuit. In student texts it is defined as

V = I x R.

Where V = Voltage drop across the element.

I = Current flowing through the element.

R = Resistance of the element.

A voltage of 1 Volt is required to drive a current of 1 Ampere through a resistance of 1 Ohm.

Series Circuit: A series circuit has its elements connected such that current leaves one element and flows directly into another, for all elements in the circuit ie. the elements in the circuit are connected sequentially.

Parallel Circuit: a parallel circuit has elements connected such that current flow is split between two or more elements ie. the elements within the circuit are connected in parallel with each other.

Battery: for practical purposes, is an energy source with a constant voltage across its terminals.

APPENDIX 2

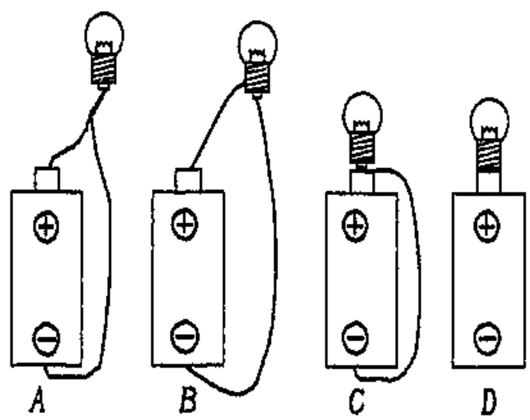
ELECTRICITY
SURVEY

The following is a survey to find out <u>your</u> ideas about electricity. It is <u>not</u> part of your assessment. The class results of this test will be used to identify areas of study during the next few weeks.

Read each question carefully and then give an answer. <u>Do</u> <u>not</u> miss answering any questions. Remember this is a survey and it is <u>your</u> <u>opinion</u> in which I am interested.

TEST COMPOSITION
20 Multiple choice questions
5 Short answer questions

1. *In which case would the globe glow?*



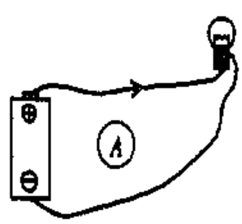
a) A

b) B

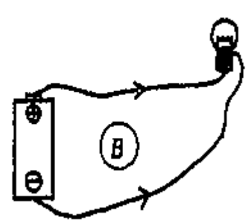
c) C

d) D

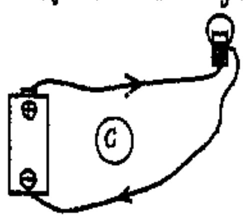
2. *Which of the following diagrams best describes the current in the wire (s) to make the globe glow?*



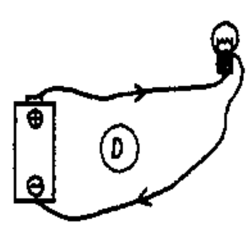
There will be no current in the wire attached to the base of the battery.



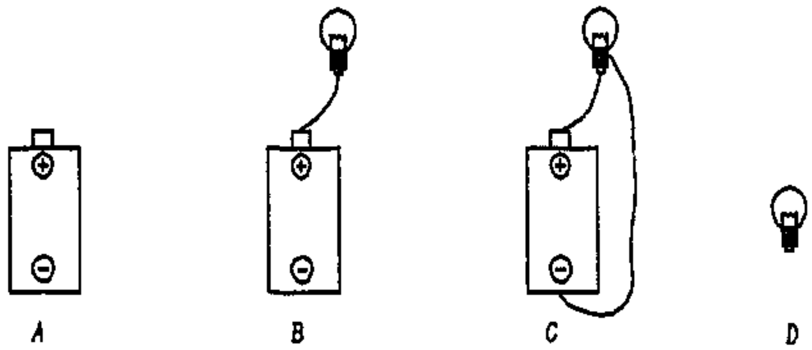
The current will be in a direction toward the globe in both wires.



The direction of the current will be as shown. The current will be less in the 'return' wire.



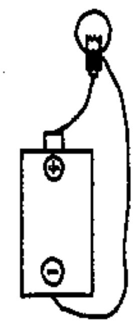
The direction of the current will be as shown. The current will be the same in both wires.



3. In which case(s) is there a circuit?
   (a) B and C
   (b) B only
   (c) C only
   (d) none of the cases

4. In which case(s) is there an electric current?
   (a) A
   (b) B
   (c) C
   (d) B and C

5. In which case(s) is there a voltage present?
   (a) A only
   (b) B and C only
   (c) A, B and C
   (d) All



6. The globe uses up part of the electric <u>current</u>.

(a) True (b) False

7. The globe uses up some of the <u>energy</u> of the electric current.

(a) True (b) False

8. Diagrams 1 and 2 have the same size batteries but the globe in diagram 2 has a bigger resistance.

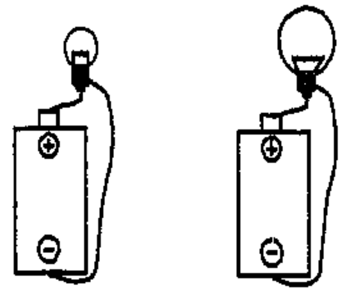


Diagram 1 Diagram 2

There is more current in diagram 2 than in diagram 1

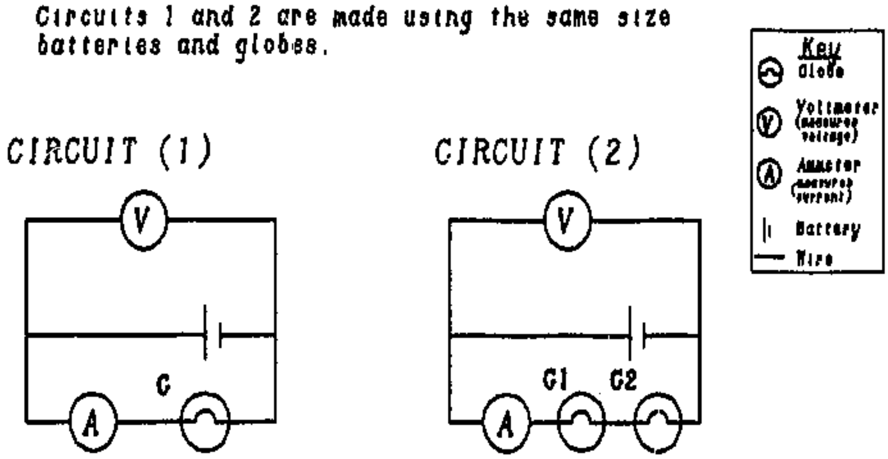
(a) True (b) False

Explain your choice. ______________________________

____

USE THE DIAGRAMS BELOW TO ANSWER QUESTIONS 9-13.

Circuits 1 and 2 are made using the same size batteries and globes.



9. In circuit 2, globe G2 shines less brightly than globe G1.

(a) True (b) False (c) I don't know

Explain your choice ____

10. Globes G1 and G2 shine less brightly than globe G.

(a) True (b) False (c) I don't know

Explain your choice ____

11. There is a lower voltage shown by the voltmeter (V) in circuit (2) than in circuit (1).

(a) True (b) False (c) I don't know

Explain your choice ______________________________

____

12. There is less current shown by the ammeter (A) in circuit (2) than in circuit (1).

(a) True (b) False (c) I don't know

Explain your choice ______________________________

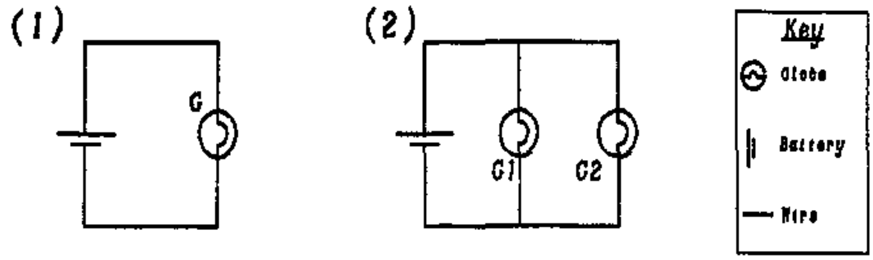
____

13. The battery delivers the same voltage in both circuits.

(a) True (b) False (c) I don't know

Explain your choice ______________________________

____



14. The voltages across globes G1 and G2 are equal.

(a) True (b) False (c) I don't know

Explain your choice ______________________

____

15. The voltages across G1 and G2 are less than that of G.

(a) True (b) False (c) I don't know

Explain your choice ______________________

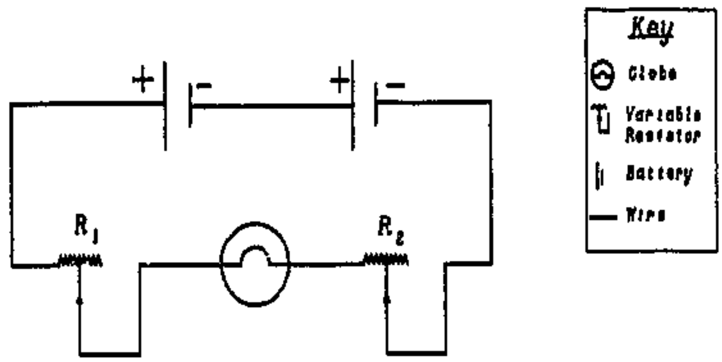
____

16. Globes G1 and G2 shine less brightly than globe G.

(a) True (b) False (c) I don't know

Explain your choice ______________________

____



17. *If R1 is decreased, the brightness of the globe will...*

(a) Increase (c) Stay the same
(b) Decrease (d) I don't know

18. *If R2 is increased, the brightness of the globe will...*

(a) Increase (c) Stay the same
(b) Decrease (d) I don t know

19. *If R1 is increased, the brightness of the globe will...*

(a) Increase (c) Stay the same
(b) Decrease (d) I don't know

20. *If R2 is decreased, the brightness of globe will ...*

(a) Increase (c) Stay the same
(b) Decrease (d) I don't know

SHORT ANSWER SECTION QUESTIONS 21-25.

EXPLAIN YOUR MEANING FOR EACH OF THE FOLLOWING TERMS.

21. Current ______________________

22. Voltage ______________________

23. Resistance ______________________

24. Battery ______________________

25. Circuit ______________________

Test Answers Total 25 marks

Multiple Choice Section

	Answer	*Reason*
1.	B	(not applicable)
2.	D	(not applicable)
3.	C	(not applicable)
4.	C	(not applicable)
5.	C	(not applicable)
6.	B	(not applicable)
7.	A	(not applicable)
8.	B	When the resistance is increased the current is decreased
9.	B	When the resistance is increased the current is decreased
10.	A	When the resistance is increased the current is decreased
11.	B	There is the same voltage in both circuits
12.	A	When the resistance is increased the current is decreased.
13.	A	There is a constant voltage source
14.	A	The total voltage decreases
15.	B	The total voltage drop is the same
16.	B	When the resistance is increased the current is decreased
7.	A	(not applicable)
18.	B	(not applicable)
19.	B	(not applicable)
19.	B	(not applicable)
20.	A	(not applicable)

20 marks
(20 at 1 mark each)

Short Answer Section (accept two out of the three criterial attributes)

21. Electron, flow, circuit
22. Force, pushing, electrons
23. Opposition, electron, flow
24. Source, electrical, energy
25. Pathway, electron, flow

5 marks
(5 at 1 mark each)

APPENDIX 3

INTERVIEW SCHEDULE AND DIAGRAMS.

Interview Schedule

Section 1.

Given a globe, three wires and a battery, draw a circuit through which electricity can pass to light up the globe? (See figure 1.)

Section 2.

Given these two possible ways to connect a light bulb to a battery describe whether the bulb will light or not? Explain your answer. (See figure 2.)

Section 3.

Look at these figures, (See figure 3.) in which of these situations;

a) will the globe glow?

b) will there be electric current?

c) will there be a voltage present?

Section 4.

In this diagram the bulb is connected to the battery and it is lit. (See figure 4.) In this situation what do you think is happening to the current? (Inquire as to whether the bulb is considered to be consuming part of the electric current or part of the energy of the electric current?)

Section 5.

Given this series circuit, (See figure 5.) indicate, using arrows the direction in which current flows to make the globe glow.

Section 6.

Do any of these diagrams describe the way you think electric current flows in the wires to make the globe glow? (See figure 6.) If not how does the current flow? **Note**: in diagram 'A' there will be no electric current in the wire attached to the base of the battery. In diagram 'B' the electric current will be in a direction towards the bulb in both wires. In diagram 'C' the direction of the electric current will be as shown but the current will be less in the return wire and in diagram 'D' the direction and the amount of the electric current will be the same in both the wires.

Section 7.

Thinking about batteries:

a) Does a battery deliver the same electric current whatever the circuit?

b) Does a battery deliver the same voltage what ever the circuit?

Section 8.

In this circuit there are resistors which can either be increased or decreased. (See figure 7.)

a) If R_1 is decreased what will happen to the brightness of the globe?

b) If R_2 is increased what will happen to the brightness of the globe?

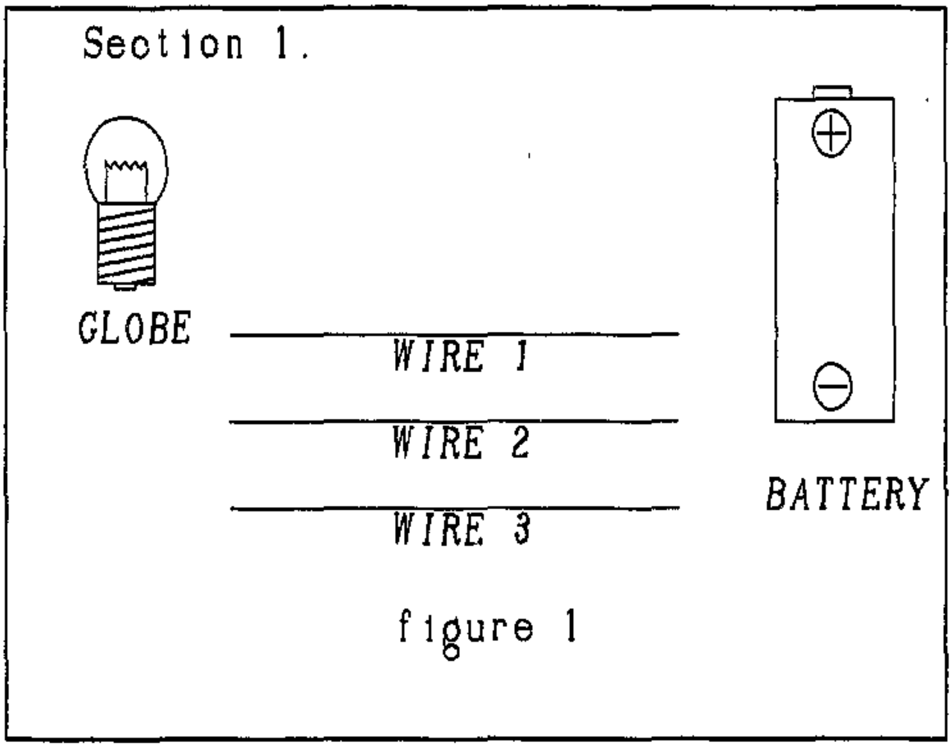
c) If R_1 is increased what will happen to the brightness of the globe?

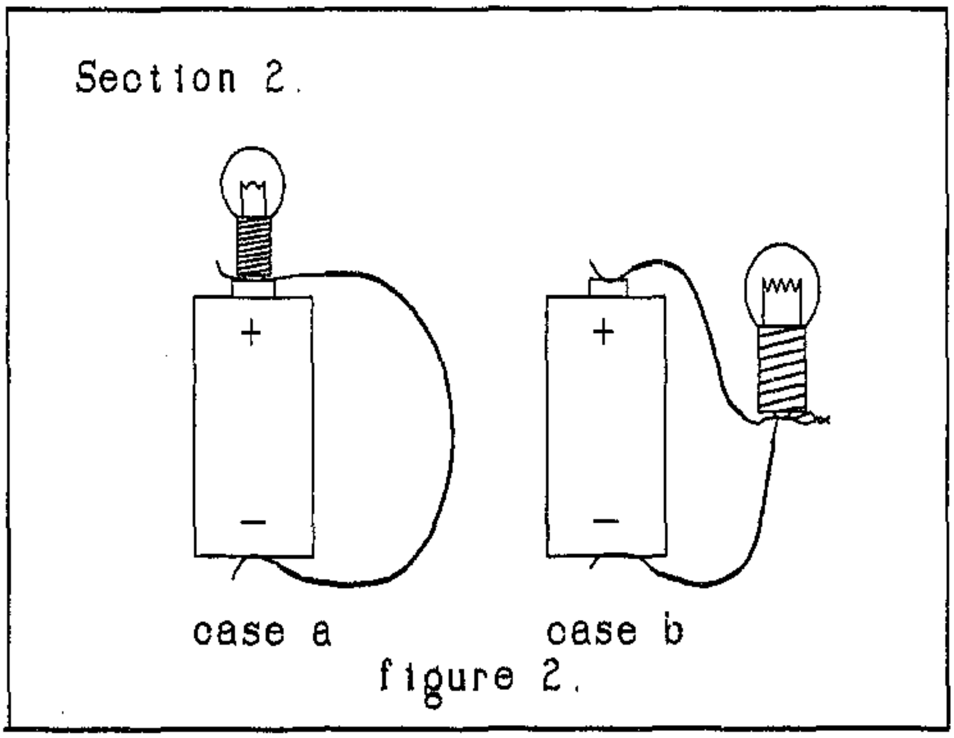
d) If R_2 is decreased what will happen to the brightness of the globe?

Section 9.

Have you ever heard of the term Volt? Can you give an example of where the term is used? What do you think the term means?

Interview Diagrams





Section 3.

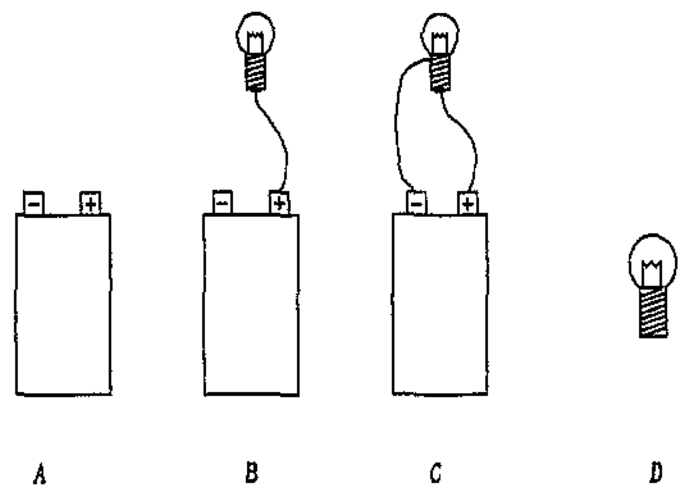


figure 3.

Section 4.

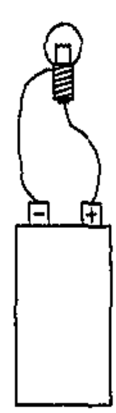


figure 4.

Section 5.

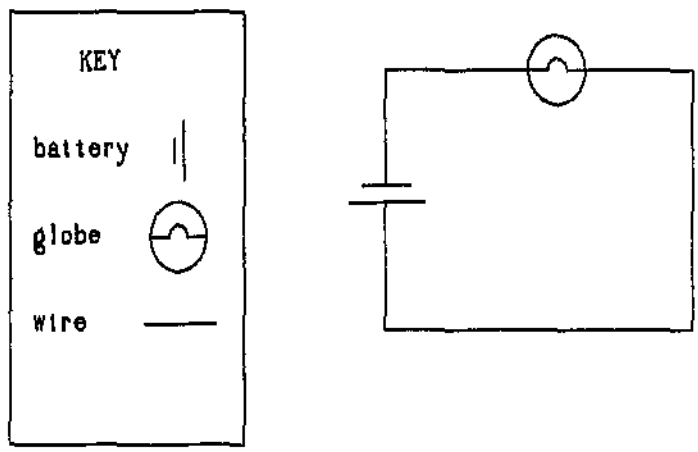


figure 5.

Section 6.

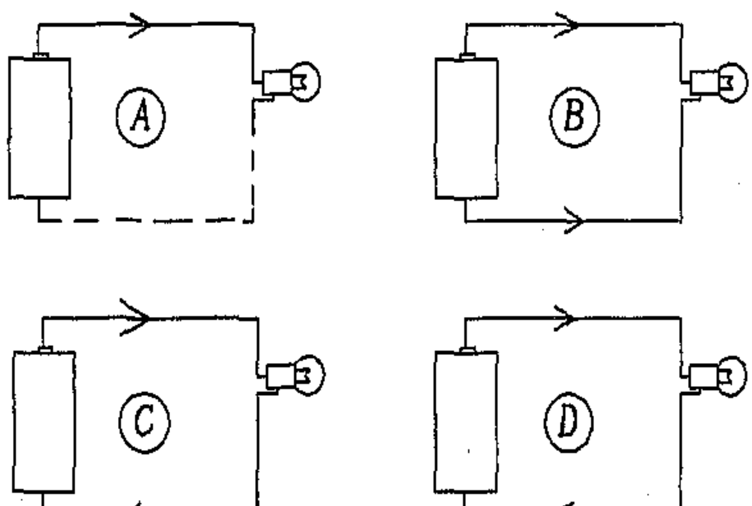


figure 6.

Section 8.

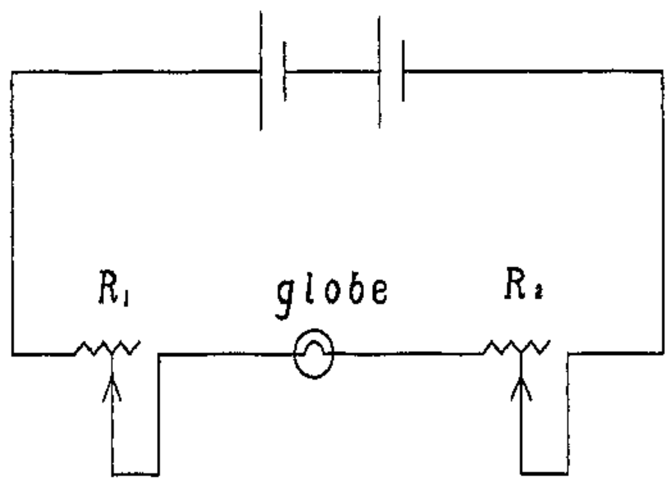


figure 7 .

APPENDIX 4

TRANSCRIPT OF POST INSTRUCTION INTERVIEW WITH STUDENT NUMBER B27

Section One

I: Matthew given a globe, three wires and a battery, how would you connect up a circuit through which electricity can pass to light up the globe?
S: Well I would get the first wire and put one in on the negative and pass it to the globe and with another wire I would put it on the positive and pass it to the globe.
I: Could you do that for me on the diagram.
S: And they are probably both on the side but probably on the bottom part as well.

Section Two

I: Given these two possible ways to connect a light bulb to a battery describe whether the bulb will light or not in each case. Will it light up in Globe A?
S: Well in Globe A I don't think it would light up.
I: Why not?
S: Because I think you need two separate wires for a complete circuit in this case, because it needs to go from negative to positive and at the start it's going straight from the positive to the globe.
I: Okay what about in Case B will the globe light up in Case B?
S: I would say that it would probably would light up in Case B.
I: Okay, why is that.
S: Because there is a separate wire running from the negative to the globe and also the electricity can pass through and go back to the positive.

Section Three

I: Okay having a look at Section three, look at these figures, in which of these situations will the globe glow?
S: C.
I: Why C?
S: Because there is a circuit.
I: Will it glow in any of the others?
S: No.
I: Why not?
S: Because in "A" there's no globe, in "B" there's no way of electricity going from negative to the globe. and in "D" there's no battery.
I: Okay, in which of those cases will there be an electric current?
S: "C"
I: Any others?
S: No.
I: Why not.
S: Because it can't travel anywhere the voltage and in "B" it has to go through negative first, and in D there is no voltage pressure.

I: Okay, in which of the situations is there be a voltage present?
S: "A", "B" and "C".
I: Why is that?
S: Because there is a battery for every single one.

Section Four

I: In this diagram the bulb is connected to the battery and it is lit. In this situation what do you think is happening to the current? Could you show me?
S: The negative to the battery and the battery back to the positive
I: Does the bulb consume any of the electric current
S: Yes
I: Okay, what part of the current?
S: Ah, the energy.
I: What are you saying current is?
S: Current is the flow of electrons.
I: So does it use any of the electrons?
S: Yes. the energy is carried in the electrons.

Section Five

I: Okay, if you have a look at Section five then given that this series circuit, indicate, using arrows the direction in which current flows to make the globe glow.
S: Are you allowed to tell me which one is negative and which one is positive?
I: Yes I can. Negative is the short one.
S: Okay.

Section Six

I: These are different ways that students think that current flows in a circuit. Some people think that it comes out of the battery and goes to the globe, and there is a wire back here but no electricity flows through it. Some people think that electricity comes out of the top and some comes out of the bottom and they meet in the globe. Other people think that electricity comes out of the top goes to the globe and a little bit comes back to the bottom and some people think that some comes out of the top, goes to the globe, and the same amount goes back to the battery. Do any of those represent how you think electricity flows?
S: Oh probably "C" would be the closest.
I: Why do you say "The closest"?
S: Ah, because there's still some coming back to the battery from the globe and like there is a circuit going back and forth.
I: Is there another way you think it should go?
S: No I don't think so.

Section Seven

I: Thinking about batteries for a moment does a battery deliver the same electric current whatever the circuit?
S: Yes.
I: Okay. Does a battery deliver the same voltage what ever the circuit?
S: Yes.
I: Why does it deliver the same electric current in whatever circuit it's in?
S: Because the battery has the same voltage in each case.

Section Eight

I: Have a look at this diagram. In this circuit there are resistors which can either be increased or decreased. If R_1 is decreased what will happen to the brightness of the globe?
S: It will stay the same.
I: Why is that?
S: Because that will not effect the current flow going from the negative to the globe.
I: If R_2 is increased what will happen to the brightness of the globe?
S: The globe will become dimmer.
I: Why is that?
S: Because there will be larger resistance which will be stemming the flow of the current and there will be less going to the globe.
I: If R_1 is increased what will happen to the of the globe?
S: Nothing will happen because it won't effect the globe because its half through.
I: Okay what will happen if you decrease R_2? What will happen to the brightness of the globe?
S: The globe will become brighter.
I: Why is that?
S: Because it will allow more current or electrons to flow through and to reach the bulb.

Section Nine

I: Okay, this is not a picture now this is just the last question. Have you ever heard of the term Volt?
S: Yes.
I: Can you give an example of where the term is used?
S: On a battery.
I: Ah hah, anywhere else.
S: Ah, on a electrical post to hold the wires up.
I: What do you think the term means?
S: The driving force of electrons that pushes them along.
I: Okay, right, thanks very much.